Simple Protocols to Determine Dust Potentials from Cattle Feedlot Soil and Surface Samples

Daniel N. Miller* and Bryan L. Woodbury

ABSTRACT

Cattle feedlot dust is an annoyance and may be a route for nutrient transport, odor emission, and pathogen dispersion, but important environmental factors that contribute to dust emissions are poorly characterized. A general protocol was devised to test feedlot samples for their ability to produce dust under a variety of environmental conditions. A blender was modified to produce dust from a variety of dried feedlot surface and soil samples and collect airborne particles on glass fiber filters by vacuum collection. A general blending protocol optimized for sample volume (150–175 cm³), blending time (5 min of pre-blending), and dust collection time (15 s) provided consistent dust measurements for all samples tested. The procedure performed well on samples that varied in organic matter content, but was restricted to samples containing less than 200 to 700 g H_2O kg^{-1} dry matter (DM). When applied to field samples, the technique demonstrated considerable spatial variability between feedlot pen sites. Mechanistically, dust potential was related to moisture and organic matter content. An alternative protocol also demonstrated differences within pen sites in maximum dust potential and dust airborne residence time. The two protocols were not intended, nor are they suitable, for predicting actual particulate matter emissions from agricultural sources. Rather, the protocols rapidly and inexpensively compared the potential for dust emission from samples of differing composition under a variety of environmental conditions.

A GRICULTURAL DUST HAS many origins and causes including wind-blown soil emissions, dust generated during animal feed processing, and dust dander in swine houses. Recently, negative aspects of dust emitted from animal feeding operations (poultry, swine, dairy, and beef cattle) have drawn public and regulatory scrutiny, but adequate information about emissions is lacking (National Research Council, 2002). In swine production, the relationships between dust sources, building concentrations, and human and animal health effects have been documented (Carpenter, 1986; Hartung, 1986; Seedorf, 1997). Swine dust also has been identified as a vehicle for odor transport (Hartung, 1986; Hoff et al., 1997), but its role in other animal production systems has not been as clearly described.

Cattle feedlots have long been identified as dust sources (Carroll et al., 1974), but the relationships between diverse environmental factors, dust generation, and particulate matter emissions at cattle feedlots are poorly understood. Conceptually, soil or manure moisture plays a key role in dust emissions, and field studies have documented a negative correlation between dust concentrations immediately downwind from cattle feedlots and feedlot surface moisture (Sweeten et al., 1988). Water sprinklers and greater cattle stocking densities have been recommended to control dust at cattle feedlots by increasing soil and manure moisture into the range of 20 to 41% (Auvermann and Romanillos, 2000; Sweeten et al., 1988; Sweeten, 1998), but too much moisture may increase odor. Altering feeding strategies has also recently been shown to decrease dust concentrations (Wilson et al., 2002). The strength of these studies is the actual measurement of emitted dust particles from working feedlots. However, further research into mechanisms affecting dust generation needs to be conducted.

Techniques at the field-scale level are available to measure airborne dust concentrations and dust emissions from surfaces. High-volume air samplers using a variety of methods to concentrate dust are typically used to measure dust concentration in a known air volume (Carpenter, 1986). At a smaller field scale (several square meters), wind tunnels have been used to evaluate the effect of differing soil types and treatments on wind erosion (Saxton et al., 2000). A recently published report by Chandler et al. (2002) describes a method for measuring dust emissions from soil samples in the laboratory but involves a complex, yet highly effective, design to simulate wind erosion. The objectives of this study were to (i) develop a simple, rapid, and inexpensive laboratory method to compare dust potential from a variety of feedlot soils that undergo more vigorous physical abrasion and suspension due to cattle activity; (ii) describe the operational parameters and limits that yielded consistent results; and (iii) examine the effect of moisture and organic matter content on potential dust emissions from feedlot surfaces.

MATERIALS AND METHODS

Soil and Manure Collection

Soil and feedlot surface samples were collected at the 6000-head-capacity, open-air beef cattle feedlot at the USDA Agricultural Research Service, U.S. Meat Animal Research Center located in south-central Nebraska. The feedlot was constructed on a Hastings silt loam (fine, smectitic, mesic Udic Argiustoll). Feedlot surface samples consisted of varying mixtures of manure and soil and were collected from the top 2 cm of loose surface material at three sites in a typical feedlot pen. These sites were immediately behind the feed bunk, on the top of the central mound, and near the down-gradient end. A soil sample was collected from surface soil (top 2 cm) in the drainage ditch immediately below the pen that received

Abbreviations: DM, dry matter.

pen runoff. These feedlot samples were selected because they represented the range of soil and manure mixtures that might be collected from this feedlot. Cattle in this pen were fed 5.1 kg DM per steer daily of a diet that contained 70% corn (*Zea mays* L.) silage and 30% alfalfa (*Medicago sativa* L.) haylage on a DM basis. All samples were dried for 4 to 15 h at 105°C to remove excess water and sieved through a screen (4-mm opening) before their use in dust generator experiments. Moisture and organic matter content were determined in manure and soil subsamples (Table 1) by mass loss after drying overnight at 105°C for moisture content, and then by mass loss-on-ignition at 425°C overnight for organic matter content (Nelson and Sommers, 1996).

Blender Modification for Dust Production

A two-speed blender (Model 51BL31; Waring Commercial, Torrington, CT) was modified to produce and collect airborne dust samples (Fig. 1). The central plastic piece on the vinyl lid from a 1-L container was removed and replaced with a rubber stopper (Size #11.5) containing two 6-mm access holes. Two 30-cm lengths of plastic tubing (6-mm o.d.) were then inserted into each hole. One tube was connected to a vacuum source and the other tube remained open and served as an air inlet tube for the system. Use of the air inlet tube reduced dust escaping through the vent hole during the blending operation. The male end of a 25-mm Easy Pressure Syringe Filter Holder (Pall Gelman, Ann Arbor, MI) was then connected to the end of the vacuum line exposed inside the glass blender container. A pre-weighed Type A/E glass fiber filter was placed on the support screen of the filter holder followed by a rubber O-ring seal. The cap of the filter holder (female luer inlet) was enlarged to a 20-mm diameter and screwed onto the base of the filter holder. Expanding the inlet diameter to 20 mm provided better dust distribution across the filter surface. It should be noted that the O-ring on the filter was not compromised by this modification. When samples were blended, the blender was run at low speed (18 000 rpm; 48-mm blade diameter). House vacuum was used to create a flow of air through the system for dust collection. Initial air flow through the dust generator (filter in place, no dust collected)

Table 1. Moisture and organic matter (OM) content of cattle feedlot surface samples and ditch soil evaluated for dust potential.

| Sample†	Moisture content	OM content
	g H$_2$O kg^{-1} dry matter	g OM kg^{-1} dry matter
Feed bunk	1180	637
Mound	53	431
Down-gradient	44	330
Ditch	473	64

† The cattle feedlot was constructed on a Hastings silt loam soil. Feed bunk, mound, and down-gradient samples were composite samples collected from a single feedlot pen. The ditch sample was collected from a drainage ditch immediately below the pen.

was 10.2 L min^{-1} at 25°C and 0.101 MPa (1 atmosphere). Initial and subsequent air flow were measured using a wet test meter (Petroleum Analyzer Co., Pasadena, TX). Dust potential was defined as the mass of airborne particles collected on the pre-weighed filter during a 15-s vacuum collection interval unless noted otherwise.
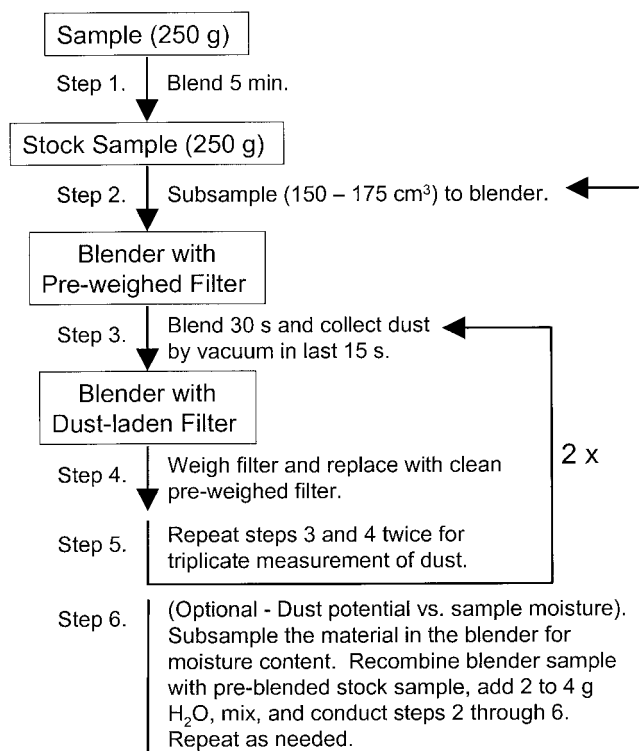
System Optimization

We hypothesized that the duration of blending before dust sample collection, the amount of sample, time for dust sample collection, and properties of the sample (i.e., moisture and organic matter content) would affect the amount of sample dust collected on the filter. The feedlot drainage ditch soil was used to evaluate the effect of these parameters on dust collection. Additionally, the feedlot pen surface samples (feed bunk, mound, and down-gradient) were used to verify that the dust generator operated properly when samples varied.

The effect of blending time before dust collection and the effect of collecting multiple dust potential samples from a single sample were evaluated using the feedlot ditch soil. Two hundred grams (134 cm^3) of unblended feedlot ditch soil was placed into the blender and blended for 30 s. After the 30-s blending interval, a pre-weighed filter was placed into the holder, and airborne particles were collected on the filter by vacuum during a subsequent 15-s blending pulse. Another pre-weighed filter was then placed into the holder, and airborne
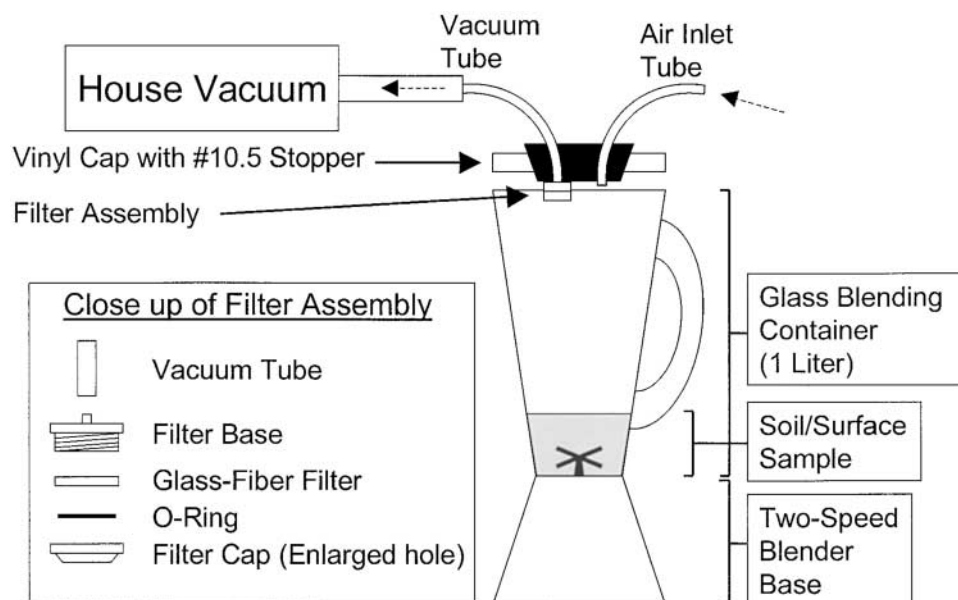
Fig. 1. Schematic for converting a standard laboratory blender into a dust generator. Dashed arrows indicate direction of air flow into and out of the dust generator.

Sample (250 g)

Step 1. Blend 5 min.

Stock Sample (250 g)

Step 2. Subsample (150 – 175 cm³) to blender.

Blender with
Pre-weighed Filter

Step 3. Blend 30 s and collect dust
by vacuum in last 15 s.

Blender with
Dust-laden Filter

Step 4. Weigh filter and replace with clean
pre-weighed filter.

Step 5. Repeat steps 3 and 4 twice for
triplicate measurement of dust.

2 x

Step 6. (Optional - Dust potential vs. sample moisture).
Subsample the material in the blender for
moisture content. Recombine blender sample
with pre-blended stock sample, add 2 to 4 g
H_2O, mix, and conduct steps 2 through 6.
Repeat as needed.

Fig. 2. The general protocol developed for determining the dust potential of soils and feedlot surface samples including an optional step for determining the dust potential over a range of moisture.

particles were collected on the filter by vacuum during a final 15-s blending pulse. This procedure (30 s of blending followed by two 15-s blending pulses with dust collection) was conducted 20 times on the same ditch soil sample so that the cumulative time of blending on the ditch soil sample was 20 min. The linear regression procedure of SAS Version 7.0 (SAS Institute, 1998) was used to estimate the slopes of dust potential versus cumulative blending time and determine if the slopes differed from zero.

The optimum amount of sample (mass and volume) to maximize the mass of dust on the filter (dust potential) was determined using all samples. Five-hundred-gram stocks of ditch soil or feedlot surface sample were pre-blended for 5 min before use based on results of initial experiments on cumulative blending time. For each of the samples (ditch soil and three feedlot surface soils), 25 g of pre-blended sample was added to the blender and blended for 30 s. Airborne particulate matter was collected on a pre-weighed filter during the last 15 s of the blending interval. Two additional dust samples were collected from the same mass sample in a similar manner (new pre-weighed filter, blend 30 s, collect dust by vacuum during the last 15 s of blending) for a total of three replicate dust potentials for a particular mass of sample. After collecting the three dust samples, an additional 25 g of sample was added to the sample already in the blender, and three more dust samples were collected. This process (add 25 g of sample and collect three dust samples) was continued until the average mass of dust collected on the filters was <15 mg. Zero mass (or volume) samples were made as described above in an empty blender (no ditch soil or feedlot surface sample in the blender). The pre-blended sample volume of each sample tested was determined using a graduated cylinder. Data were analyzed by analysis of variance (ANOVA) using the GLM procedure of SAS. The model was by sample type and used either mass or volume as a main effect. The range of optimum sample masses or volumes for each sample was determined as the range of masses or volumes that did not differ ($P \geq 0.01$) from the maximum dust potential measured in each sample.

The time of dust collection was varied to determine the maximum dust-holding capacity of the filters using 200 g (134 cm³) of feedlot ditch soil. The ditch soil was pre-blended for 5 min to obtain a uniform sample. Triplicate dust samples were collected on pre-weighed filters for each time period. Each time period consisted of 15 s of blending then dust collection by vacuum during continued blending. Dust collection times were made incrementally longer and ranged from 5 to 150 s. The linear regression procedure of SAS was used to estimate the slopes of dust potential versus vacuum collection time and to determine if the slopes differed from zero.

Based on the initial performance of the dust generator with ditch soil and feedlot surface samples (see Results and Discussion), a general protocol was further developed and evaluated (Fig. 2). The general protocol for a particular sample used a stock sample of 250 g of pre-blended (5 min) material and measured the dust potential from 150 to 175 cm³ of the stock sample. Dust samples were collected in triplicate during three consecutive intervals. Each interval consisted of 30 s of blending with vacuum collection during the final 15 s of the interval.

Using the general protocol, the effect of sample moisture on dust potential and protocol performance was tested using the soil and manure samples by incrementally adding distilled water and measuring the dust potential of the sample. Briefly, 250 g of each soil or manure was pre-blended for 5 min to produce a uniformly ground stock sample. One hundred grams (170 cm³) of feed bunk sample, 150 g (157 cm³) of mound sample, 150 g (168 cm³) of down-gradient sample, and 200 g (150 cm³) of ditch soil sample was the optimum amount to produce the maximum amount of dust. This amount of sample was transferred to the blender and blended for a total of 30 s, with a dust sample collected during the last 15 s of blending. Blending and dust collection were repeated two additional times (three replicates per moisture level). A 2-g subsample was then collected from the blender to measure moisture content (105°C). Sample moisture did not change during the three consecutive dust potential determinations at moisture content ranging from 15 to 300 g kg⁻¹ of dry matter ($P > 0.199$). Material in the blender was then recombined with the stock manure (or soil) sample, and distilled water (2–4 g) was added into the recombined stock material using a spray bottle. The stock manure (or soil) was then thoroughly mixed, and the prerequisite sample volume was returned to the blender for an additional round of dust collection at the higher moisture content. This process (add the optimum amount of feedlot surface material or soil to the blender, collect triplicate dust samples, subsample for moisture content, recombine blended and stock material, and add more water to increase moisture content) was then repeated until the moisture in the sample caused either an excessive load on the blender or when the sample became too sticky to fall into the cavity created by the spinning blades.

Data for dust potential versus moisture content experiments are presented as the least squares means calculated using the GLM procedure of SAS. For each soil or feedlot surface sample, data for dust potential versus moisture content of each soil or feedlot surface sample was fit using the NLIN procedure of SAS with the following equation:

$$\text{dust potential} = \text{dust}_{max} \times 10^{-(MC/10)}/[10^{-(MC/10)} + 10^{-(MT/10)}] \quad [1]$$

where MC is moisture content (g H_2O kg^{-1} DM), $dust_{max}$ is the maximum dust potential, and MT is the moisture threshold (i.e., the MC at which dust potential = $0.5 \times dust_{max}$). Both $dust_{max}$ and MT were determined through an iterative process. The CORR and REG procedure of SAS were used to evaluate the relationship between MT and organic matter (OM) content of soil and feedlot surface samples.

Alternative Protocol Using the Dust Generator

An alternative protocol was developed for the dust generator and tested using the four oven-dried (0% moisture) soil or feedlot surface samples. This protocol was slightly modified from the general protocol to better characterize differences between samples in $dust_{max}$ and the airborne residence time of dust particles. Instead of collecting dust samples while the blender was operating (general protocol), dust samples were collected immediately after the blender was shut off and over a 1-min period (0, 5, 10, 20, 40, and 60 s). Sample volume (150–175 cm^3), blender operation (5 min of pre-blending and 15 s of blending before dust collection), and dust collection time (15 s of vacuum collection) were otherwise identical to the general protocol. Triplicate dust samples were taken from each sample at each time. Data were analyzed by ANOVA using the GLM procedure of SAS. The model included sample type, time of sample collection, and sample type × time of sample collection interaction. Differences between least squares means were tested with a protected t test. Responses with $P < 0.05$ were considered to differ.

RESULTS AND DISCUSSION

All the factors that we examined (blending time, amount of sample, dust collection time, and sample type) proved to affect the amount of dust collected on the filter ($P < 0.001$). We anticipated that a minimum amount of blending was required to prepare a homogenous dust-producing sample. We hypothesized that the amount of dust collected on the filter (dust potential) would increase as the sample became more finely ground, and that eventually, the dust potential would stabilize after the sample was uniformly ground. Dust potential initially increased rapidly (13.4 mg min^{-1}, $P = 0.001$) with cumulative sample blending time during the first 4 min of blending, followed by a plateau, where dust potential increased slowly (2.6 mg min^{-1}, $P < 0.001$) with cumulative blending times greater than 4 min (Fig. 3A). Based on this data, 5 min of initial blending was deemed necessary to reach the plateau period, wherein the change in dust potential with cumulative blending time was minimized. Thus, all further experiments used soil or feedlot surface samples that were initially ground for a minimum of 5 min. We also noted that replicate samples could be taken over several minutes of cumulative blending time without incurring a large bias in dust potential measurement (Fig. 3B). Repeated sampling from this ditch soil sample showed no decrease in dust potential, and we conclude that the mass of dust in samples was sufficiently large that repeated sampling (>40) did not deplete the pool of dust available in the sample. Passive deposition did not appear to interfere with measured dust potential because control filters exposed to the procedure without vacuum collection trapped <5 mg of dust.
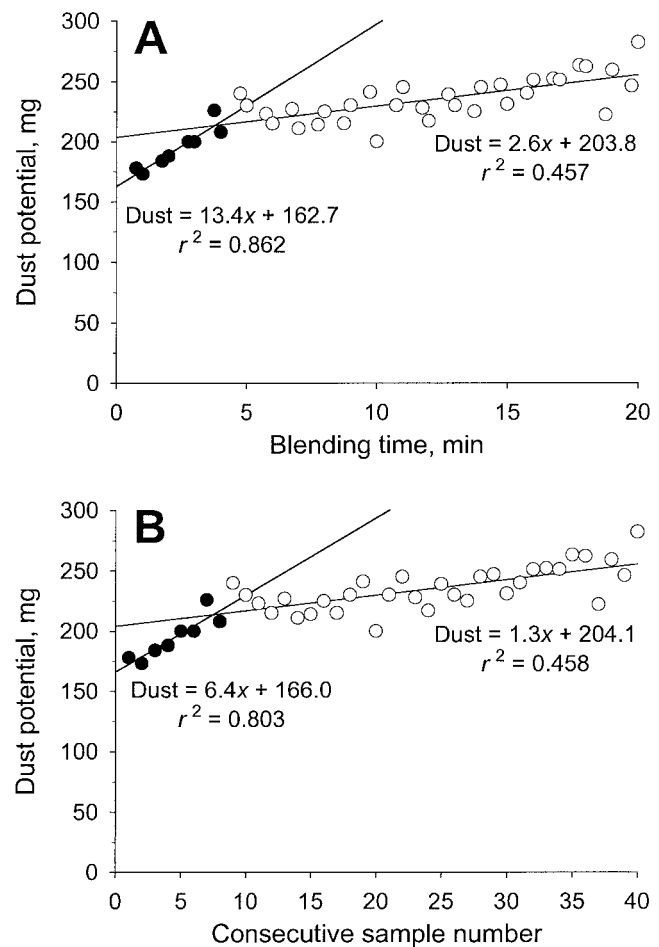

Fig. 3. Effect of (*A*) cumulative blending time and (*B*) repeated sampling from the ditch soil on dust potential. Dust potential was measured as mass of dust collected on a glass fiber filter during 15 s of vacuum collection while blending. The period of rapid dust generation is denoted using filled circles, whereas a lower rate of dust production after 4 min is denoted by open circles. All dust samples were collected consecutively from the same ditch soil sample.

Choosing the amount of sample to maximize dust potential measurement was critical for successful operation of the dust generator (Fig. 4). Maintaining a consistent inflow of soil or manure into the blades was necessary for dust production. However, if there was too much soil or manure in the blender, the sample would completely enclose the cavity caused by the blender blades, and no dust would be emitted into the blender head space. The range of sample masses for maximum dust production (defined as the range of masses that produced a dust potential that did not differ [$P > 0.01$] from the maximum dust potential) varied greatly between the samples (Fig. 4A) and did not overlap between the samples tested. Thus, the optimum mass for maximum dust production would need to be empirically determined for every sample. Sample volume proved to be a better tool than sample mass to maximize dust potential (Fig. 4B). Although each soil or feedlot sample displayed a range for optimal performance (defined as the range of volumes that produced a dust potential
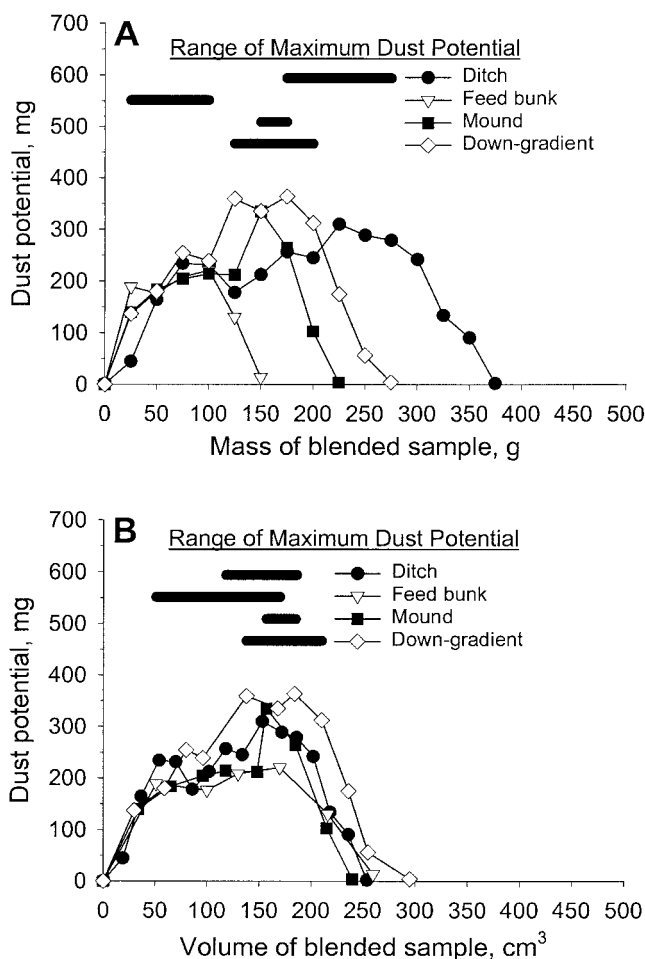
Fig. 4. Effect of (A) sample mass and (B) volume on measured dust potential (mass of dust on the filter after 15 s of vacuum collection during blender operation) from four feedlot samples. The SE of the least squares mean (n = 3) for dust potential is 17.5. The range of maximum dust potential for each sample is defined as the range of masses (or volumes) that produced a dust potential that did not differ (P > 0.01) from the maximum dust potential measurement.
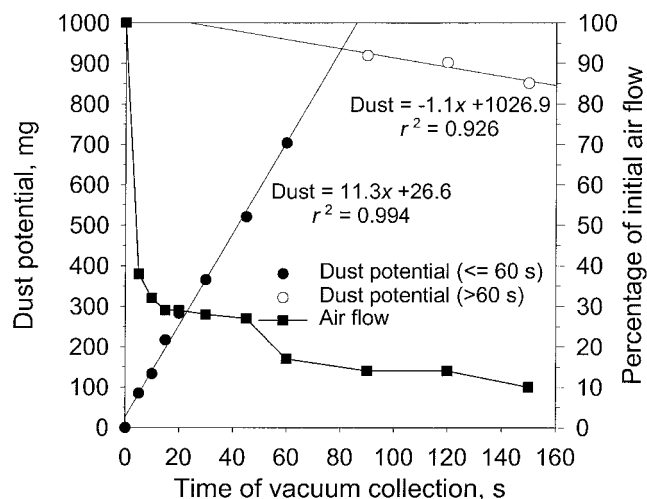

Fig. 5. Effect of vacuum collection time on the amount of dust collected on the glass fiber filter and on air flow through the dust generator. The SE of the least squares mean (n = 3) for dust potential is 25.8.

that did not differ [$P > 0.01$] from the maximum dust potential), there was a range of overlapping volumes (150–175 cm³) for all soils and feedlot surface samples. All subsequent experiments used sample volumes within this range.

Dust collection time had a strong effect ($P < 0.001$) on the mass of dust collected on the filter (Fig. 5). Dust potential increased linearly with dust collection and vacuum time (11.3 mg s⁻¹, $P < 0.001$) with a maximum capacity of approximately 900 mg. Regression analysis showed no increase or decrease with time ($P = 0.239$) at dust mass values greater than 800 mg. Based on these results, we selected a 15-s dust collection (vacuum time) for feedlot soil and surface samples.

We expected air flow to change dramatically during dust collection as the mass of dust accumulated on the filter. Measured air flow through the filter decreased by 60% within the first 5 s of vacuum collection and continued to decrease to <10% of the initial air flow as the mass of dust on the filter reached a maximum capacity of 900 mg (Fig. 5). The change in air flow,

however, was not reflected in the accumulation of dust on the filter, rather the dust accumulated at a constant rate until maximum capacity was reached. We concluded that, although the flow of dust to the filter changed with time, the rate of dust deposition remained constant and was the limiting factor.

Sample moisture was the final element evaluated to determine its effect on blender operation and dust potential. Moisture had a dramatic effect ($P < 0.001$) on the measured dust potential from various samples (Fig. 6). The upper moisture limit of the dust generator was determined to be when samples became too moist and caused excessive load on the blender motor. For the ditch soil, this occurred at >200 g H_2O kg⁻¹ DM. For the pen feed bunk, mound, and down-gradient samples, the operational limit was encountered when sample moisture exceeded 700, 500, and 430 g H_2O kg⁻¹ DM, respectively; differences in the operational limits are probably related to organic matter content. At moistures exceeding the operational limit of the dust generator, we assert that the dust potential is zero. Dust potential below the operational limit was highest when samples were driest. This is in agreement with published field observations (Sweeten et al., 1988). However, instead of a gradual decrease in dust potential with increasing moisture, there was a rapid conversion of the sample from dust-producing to dust-free with only a small increase in sample moisture. These dust potential curves agree with the field observations; the samples (mound and down-gradient) with low moisture content (53 and 44 g H_2O kg⁻¹ DM, respectively) had high dust potential (>200 mg) and were very dusty at the time of collection. The ditch soil (470 g H_2O kg⁻¹ DM) and feed bunk sample (1180 g H_2O kg⁻¹ DM) both exceeded the operational load limit of the blender (assumed zero dust potential) and did not produce any dust when they were collected in the feedlot. Moisture and dust potential curves were repeatable throughout the 90-d course of this study; in four independent trials of the ditch soil
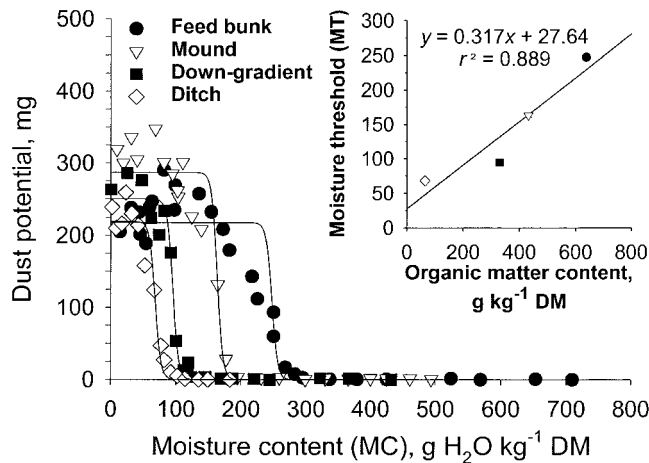
Fig. 6. Effect of sample moisture and organic matter (OM) content on dust potential from the four feedlot samples. Moisture and OM at the time of sample collection are indicated in Table 1. Values of the maximum dust potential and moisture threshold (MT; the moisture at which dust potential is half of the maximum dust potential) were calculated using regression Eq. [1]. The SE of the least squares mean ($n = 3$) for dust potential is 13.8. Inset figure shows the relationship between OM content and MT. The 95% confidence interval for MT varied from ±2.04 to 2.65 g H_2O kg^{-1} dry matter (DM) for the range of samples tested.
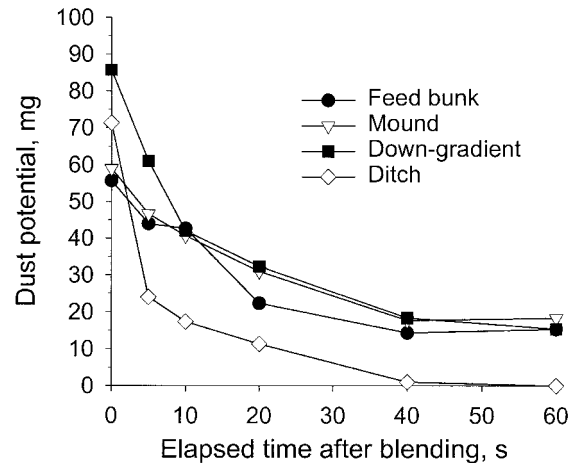

Fig. 7. Effect of sample on the airborne dust residence time using the alternate protocol. The alternate protocol differed from the general protocol by collecting airborne material immediately after the blender was stopped. The SE of the least squares mean ($n = 3$) for dust potential is 2.3.

sample, the transition between dust-producing and dust-free was consistently between 40 and 80 g H_2O kg^{-1} DM (unpublished data, 2002). We conclude from these observations that moisture variability within feedlots will lead to "hot spots" of dust production (mound and down-gradient sites).

Although the relationship between dust potential and moisture content was similar between ditch soil and feedlot surface samples, the transition from dust-producing to dust-free varied between the samples (Fig. 6). Based on initial inspection, we hypothesized that the moisture at which dust potential was half the maximum dust potential (MT) was probably related to increasing organic matter content in the samples. To calculate MT and its 95% confidence interval for each soil or feedlot surface sample, Eq. [1] was developed and fit to the data by minimizing the residual error. The calculated MT differed ($P < 0.05$) between all four feedlot samples tested. Organic matter content correlated strongly with MT ($r = 0.943$), and the slope of the regression (0.317) showed a strong tendency ($P = 0.057$) to differ from zero (inset of Fig. 6). Future research will seek to clarify this relationship; soil type is likely to be an important factor (Chandler et al., 2002; Saxton et al., 2000), but we did not evaluate other types of soils that may be found in other feedlots. However, based on these initial results, we conclude that the spatial variation in feedlot surface organic matter content is an important factor contributing to dust emission—the higher the organic matter content of the surface, the more moisture required to control dust emission.

The construction of the dust generator and its operation described here were kept intentionally simple, but the construction and operation were easily modified to examine other types of samples or other aspects of dust

emission. For example, an alternative procedure was developed whereby dust samples were collected after the blender was stopped (in the general protocol, dust samples were collected during blending). The dust potential for each sample measured using the alternate protocol (dust collection immediately after shutting off the blender) was less than the dust potential measured using the general protocol (Fig. 6 and 7). Using this alternative protocol, the measured airborne dust concentrations at 0 s varied with sample ($P < 0.001$). Ditch and down-gradient samples produced more dust ($P < 0.005$) than the feed bunk and mound samples. We believe that this measurement better reflects the total amount of dust in the blender compared with the general method, which measured a dust potential that was dependent on the deposition rate of dust on the filter. We conclude that the ditch and down-gradient samples have a larger dust emission capacity compared with the mound and feed bunk samples.

Differences in dust airborne residence time were also easier to determine using the alternate protocol. Airborne dust within the blender decreased with time (Fig. 7), and after 1 min, dust potential was zero for the ditch sample. The dust potentials from the three pen samples (feed bunk, mound, and down-gradient) after 1 min were similar to one another ($P > 0.4$) but greater than the ditch sample. Except for one difference ($P = 0.01$) at 20 s, feed bunk and mound samples produced dust that behaved identically, whereas the down-gradient sample seemed to have attributes of both ditch (i.e., rapid loss of dust particles in the first 20 s) and feed bunk and mound samples (slow loss of dust after 20 s). We would predict from these observations that dust from the feedlot pens would have a longer airborne residency time and be able to travel further from the feedlot than dust from the feedlot ditch. Other modifications and alternate protocols are possible and may include longer dust collection times or larger diameter filters for increased sensitivity for low dust potential samples.

CONCLUSIONS

Two protocols were developed to measure the relative dust potential from various feedlot soils and surfaces. Results obtained using these protocols were very reproducible when standardized for sample volume, blending time, and dust collection time. Sample moisture and organic matter content had the greatest effect on whether dust emissions were possible; dust potential was extremely high below a defined moisture threshold, which was related to organic matter content. Samples collected from different areas of the feedlot pen also indicated that the maximum potential emission of dust and its subsequent transport differs from site to site even within the same feed pen.

It is important to emphasize that the dust potential measured using the dust generator is a relative value. Predicting the actual emission of dust based on the dust potential is not possible. The utility of the dust generator technique is its ability to compare samples and predict whether dust emissions are possible and to assess the relative effect of certain treatments or dust control strategies on dust production. The dust generator is simply a new tool for researchers to conduct small-scale experiments where factors can be manipulated before conducting large-scale field studies.

REFERENCES

Auvermann, B.W., and A. Romanillos. 2000. Manipulating stocking density to manage fugitive dust emission from cattle feedyards. p. 61–70. *In* Proc. of the Innovative Technologies for Planning Animal Feeding Operations, Denver, CO. 4–6 Dec. 2000. USDA Great Plains Res. Stn., Akron, CO.

Carpenter, G.A. 1986. Dust in livestock buildings—Review of some aspects. J. Agric. Eng. Res. 33:227–241.

Carroll, J.J., J.R. Dunbar, R.L. Givens, and W.B. Goddard. 1974. Sprinkling for dust suppression in a cattle feedlot. Calif. Agric. 28: 12–15.

Chandler, D.G., K.E. Saxton, J. Kjelgaard, and A.J. Busacca. 2002. A technique to measure fine-dust emission potentials during wind erosion. Soil Sci. Soc. Am. J. 66:1127–1133.

Hartung, J. 1986. Dust in livestock buildings as a carrier of odours. p. 321–333. *In* V.C. Nielsen, J.H. Voorburg, and P. L'Hermite (ed.) Odour prevention and control of organic sludge and livestock farming. Elsevier Sci. Publ., New York.

Hoff, S.J., D.S. Bundy, and X.W. Li. 1997. Dust effects on odor and odor concentrations. p. 101–110. *In* Proc. of the Int. Symp. Ammonia and Odour Control from Animal Production Facilities, Vinkeloord, the Netherlands. 6–10 Oct. 1997. Commission Internationale du Génie Rural (CIGR), Bonn, Germany.

National Research Council. 2002. The scientific basis for estimation air emissions from animal feeding operations: Interim report. Ad hoc committee on air emissions from animal feeding operations, committee on animal nutrition. Natl. Res. Council, Natl. Academy Press, Washington, DC.

Nelson, D.W., and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p. 961–1010. *In* D.L. Sparks (ed.) Methods of soil analysis. Part 3. SSSA Book Ser. 5. SSSA, Madison, WI.

SAS Institute. 1998. SAS Version 7.0. SAS Inst., Cary, NC.

Saxton, K., D. Chandler, L. Stetler, B. Lamb, C. Claiborn, and B.-H. Lee. 2000. Wind erosion and fugitive dust fluxes on agricultural lands in the Pacific Northwest. Trans. ASAE 43:623–630.

Seedorf, J. 1997. Human health and dust related endotoxin concentrations in livestock buildings. p. 733–740. *In* Proc. of the Int. Symp. Ammonia and Odour Control from Animal Production Facilities, Vinkeloord, the Netherlands. 6–10 Oct. 1997. Commission Internationale du Génie Rural (CIGR), Bonn, Germany.

Sweeten, J.M. 1998. Cattle feedlot manure and wastewater management practices. p. 125–155. *In* J.L. Hatfield and B.A. Stewart (ed.) Animal waste utilization: Effective use of manure as a soil resource. Ann Arbor Press, Chelsea, MI.

Sweeten, J.M., C.B. Parnell, R.S. Etheredge, and D. Osborne. 1988. Dust emissions in cattle feedlots. p. 557–578. *In* J.L. Howard (ed.) Stress and disease in cattle. Veterinary Clinics of North America, Food Animal Practice. Vol. 4. No. 3. W.B. Saunders, Philadelphia.

Wilson, S.C., J. Morrow-Tesch, D.C. Straus, J.D. Cooley, W.C. Wong, F.M. Mitlohner, and J.J. McGlone. 2002. Airborne microbial flora in a cattle feedlot. Appl. Environ. Microbiol. 68:3238–3242.